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Fluid Driven Fault Slip of experimental faults subjected to fluid pressure stimulation: carbonates vs. shales

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Fluid overpressure is one of the primary mechanisms for triggering tectonic fault slip and human-induced seismicity. This mechanism is appealing because fluids lubricate the fault and reduce the effective normal stress that holds the fault in place. However, models of earthquake nucleation predict that a reduction in normal stress, as expected for fluid overpressure, should stabilize fault slip. We conducted laboratory experiments in the double direct shear configuration in a true-triaxial machine on carbonates and shale fault gouges. In particular, we: 1) evaluate frictional strength and permeability, 2) characterize the rate- and state- friction parameters and 3) study fault slip evolution during fluid pressure stimulations. With increasing fluid pressure, when shear and effective normal stresses reach the failure condition, in calcite gouges, characterized by slightly velocity strengthening behaviour and high permeability, we observe an acceleration of slip that spontaneously evolves into dynamic failure. For shale gouges, with a strong rate-strengthening behaviour and very low permeability, we document complex fault slip behavior characterized by periodic accelerations and decelerations with slip velocity that remains slow (i.e. vmax$\sim$200 μm/s), never approaching dynamic slip rates for the maximum displacement achieved in these experiments. Our data suggest that fluid overpressure can accelerate aseismic creep with the development of local frictional instability and dynamic rupture even for faults that are characterized by a velocity strengthening behavior, which indeed should favor aseismic creep. We show that fault rheology and fault stability change with fluid pressure, which suggests that a comprehensive characterization of these parameters is important for better assessing the role of fluid pressure in natural and human induced earthquakes.